

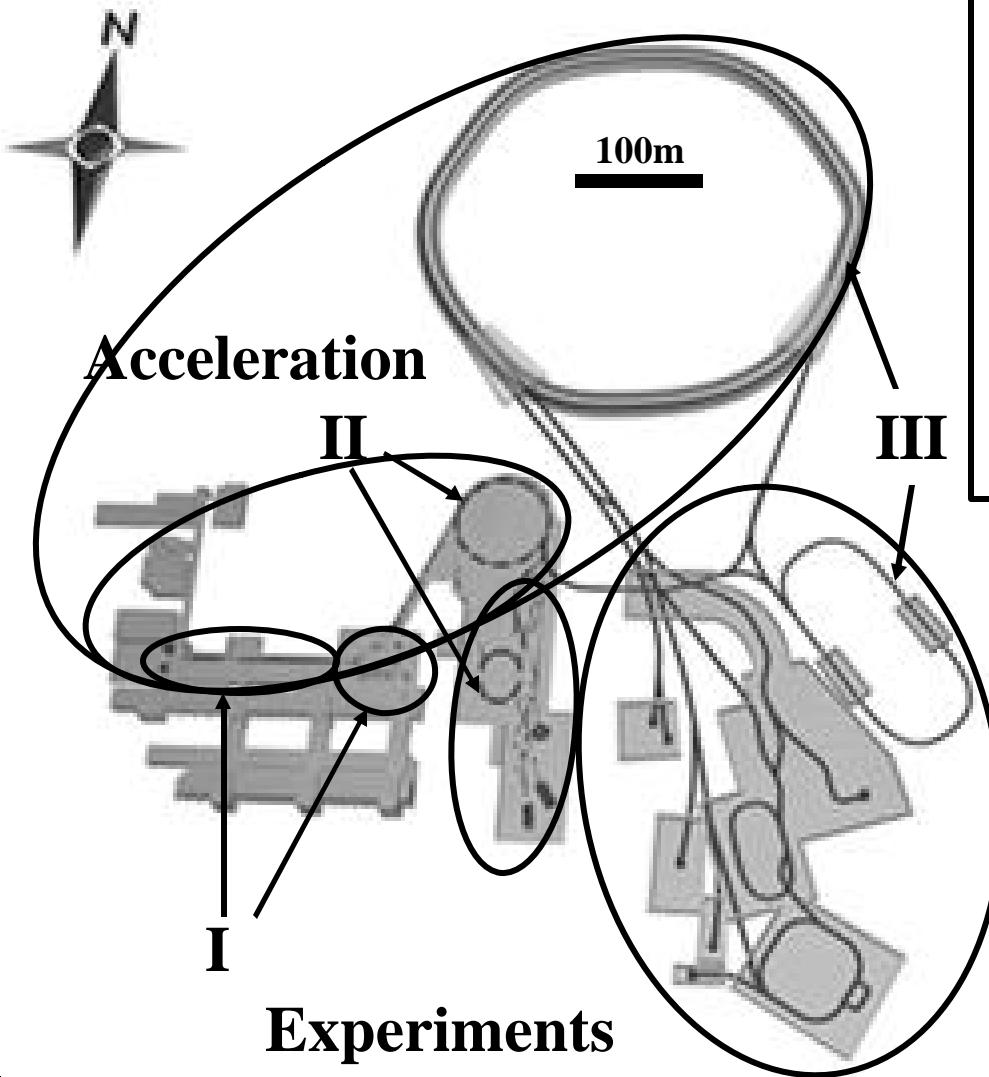
# GSI UHV System Upgrade

- The GSI Future Accelerator Facility for Beams of Ions and Antiprotons
- SIS18 UHV Status
- SIS18 UHV Upgrade
- Ion Induced Desorption
- SIS100 / SIS300 : Cryogenic UHV

*see also:*

- O. Boine-Frankenheim: "The international Accelerator Project at GSI"*
- A. Krämer: "Ion Induced Desorption Yield Measurements at GSI"*
- E. Mustafin: "Theory of Dynamic Vacuum Instability Induced by Lost Heavy Ions in Accelerator Rings"*

# The GSI Future Accelerator Facility for Beams of Ions and Antiprotons



- From protons to uranium
  - In future also antiprotons
- 1 MeV/u to 2 GeV/u
  - In future up to 30 GeV/u
- $10^9$  to  $10^{11}$  particles/cycle
  - In future  $10^{12}$  particles/cycle
- 0.1 Hz to 1 Hz Repetition rate
  - In future up to 3 Hz
- Multi-user operation: pulse to pulse ion species, full energy range

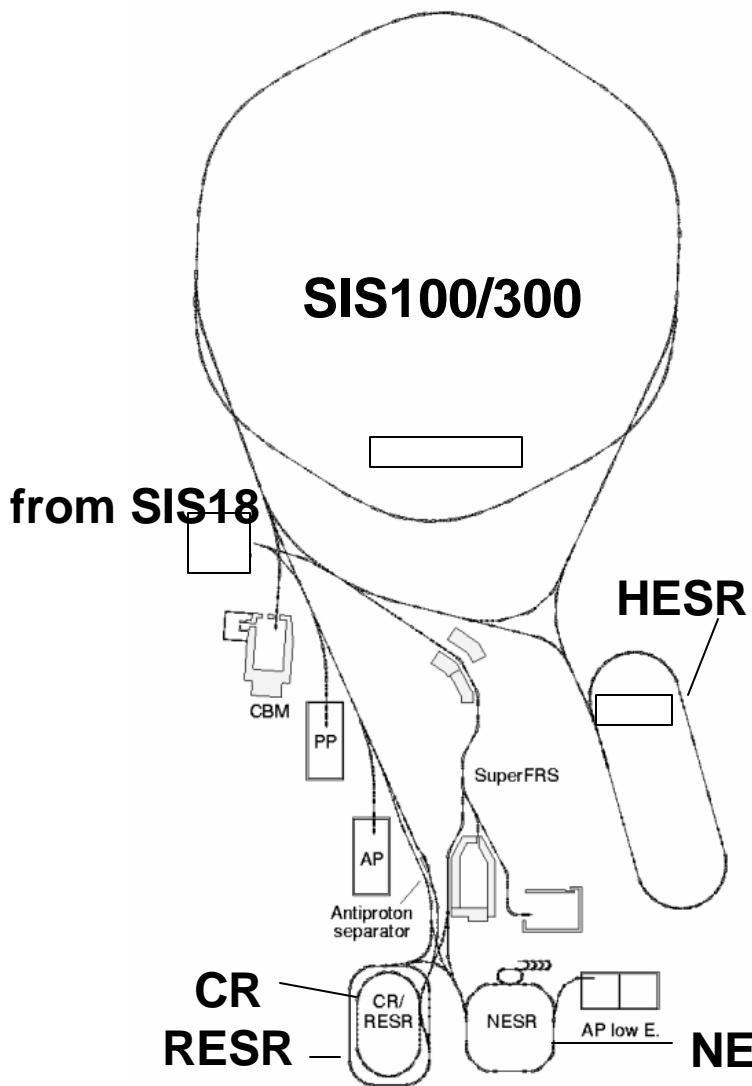
- Nuclear and Hadron Physics
- Nuclear Chemistry
- Atomic Physics
- Material Science
- Plasma Physics
- Biophysics

see: O. Boine-Frankenheim: "The international Accelerator Project at GSI"

# The GSI Future Accelerator Facility for Beams of Ions and Antiprotons



# GSI International Accelerator Facility UHV system requirements



**Due to ion beam lifetime requirements  
(e.g.: U<sup>28+</sup> in SIS18):**

**SIS18:** warm  $p \sim 5 \cdot 10^{-12}$  mbar

**ESR:** warm  $p \sim 5 \cdot 10^{-12}$  mbar

**SIS100:** cold arcs  $T=7-20K$

warm straight sections  $T=300K$

$p \sim 5 \cdot 10^{-12}$  mbar

**SIS300:** cold arcs  $T=4.2K$

warm straight sections  $T=300K$

$p \sim 5 \cdot 10^{-12}$  mbar

**NESR:**  $p \sim 5 \cdot 10^{-12}$  mbar

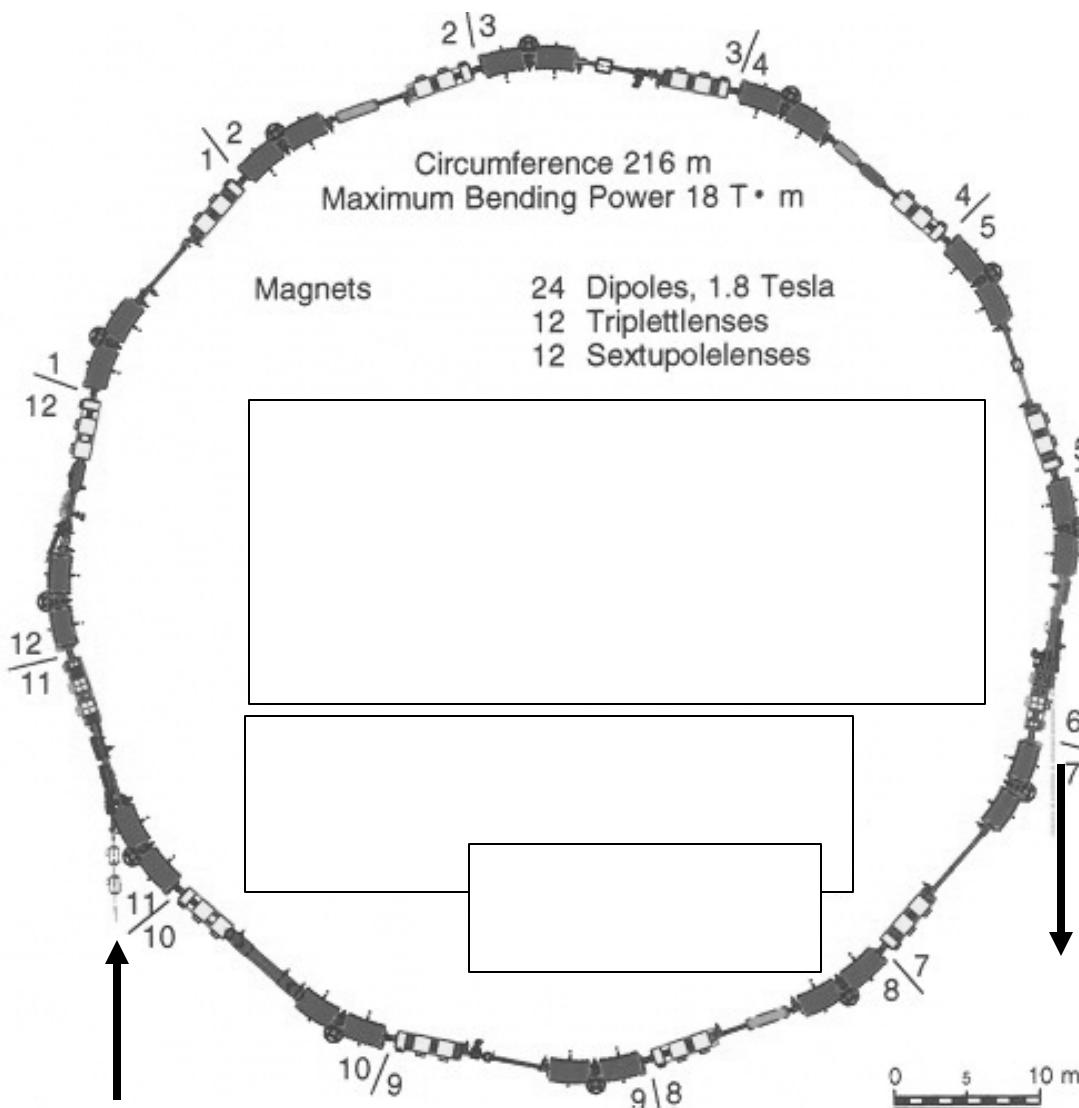
**HESR:**  $p=10^{-10}$  mbar

**RESR:**  $p=10^{-10}$  mbar

**CR:**  $p=10^{-10}$  mbar

**HEBL:** length 2.5 km, 70% cold

# The heavy ion synchrotron SIS present status

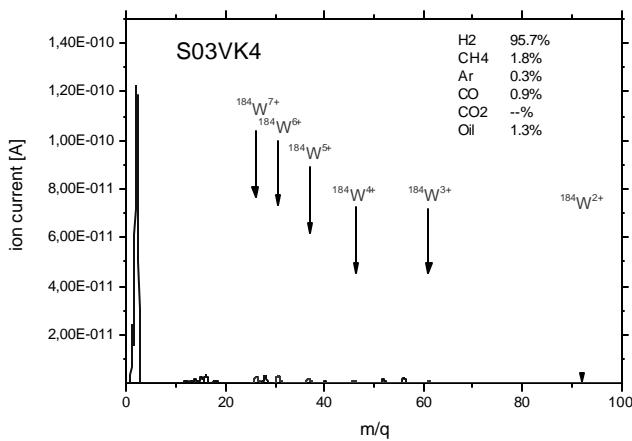
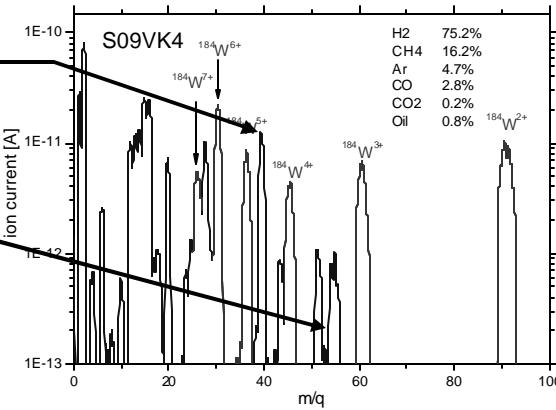
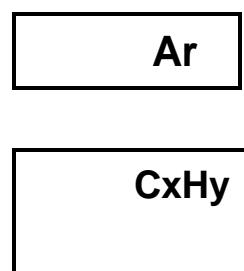
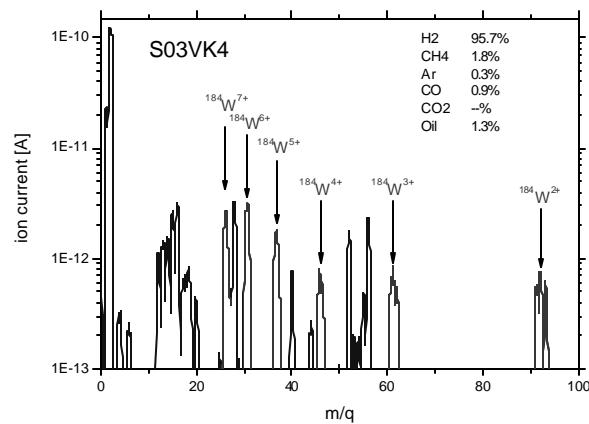


- 12 sectors each:
  - 18 m long
  - $\Delta E$  200 mm
  - 4 TSP
  - 3 Ion pumps (triode type)
  - 1-2 extractor gauge
- 7 vacuum sectors
  - One pumping station with turbo molecular pump (rough pumping + bake-out)
  - 1 RGA

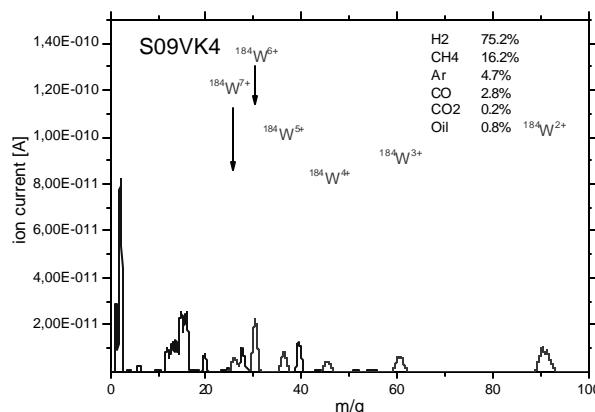
# SIS18 residual gas composition (10/2003)

## RGA spectra examples

→ existing "micro-leaks" and contaminations



S03 total pressure:  $3 \times 10^{-12}$  mbar

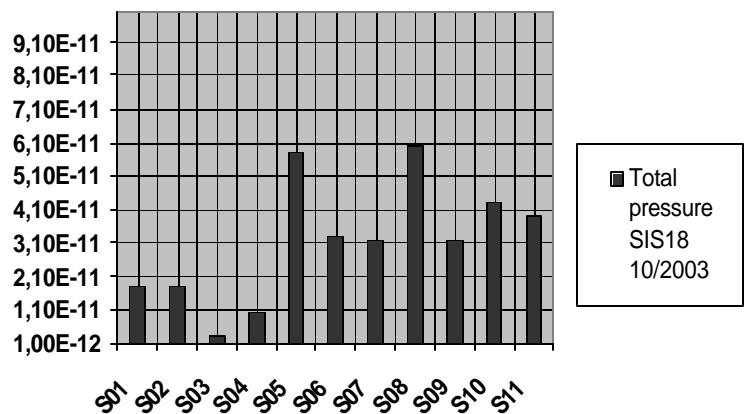


S08 total pressure:  $6.8 \times 10^{-11}$  mbar

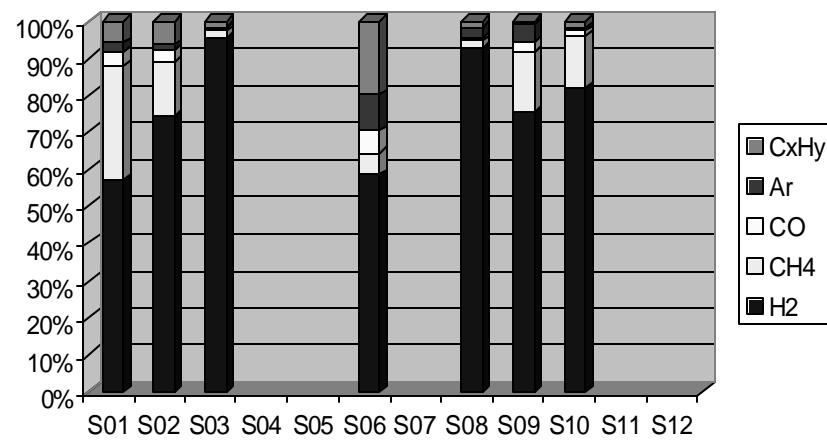
# Static conditions: SIS18 UHV Status, october 2003 (no ion beam operation)

→ Contamination of Ar, Hydrocarbons

Total pressure SIS18 10/2003



Partial pressure distribution SIS18 10/2003

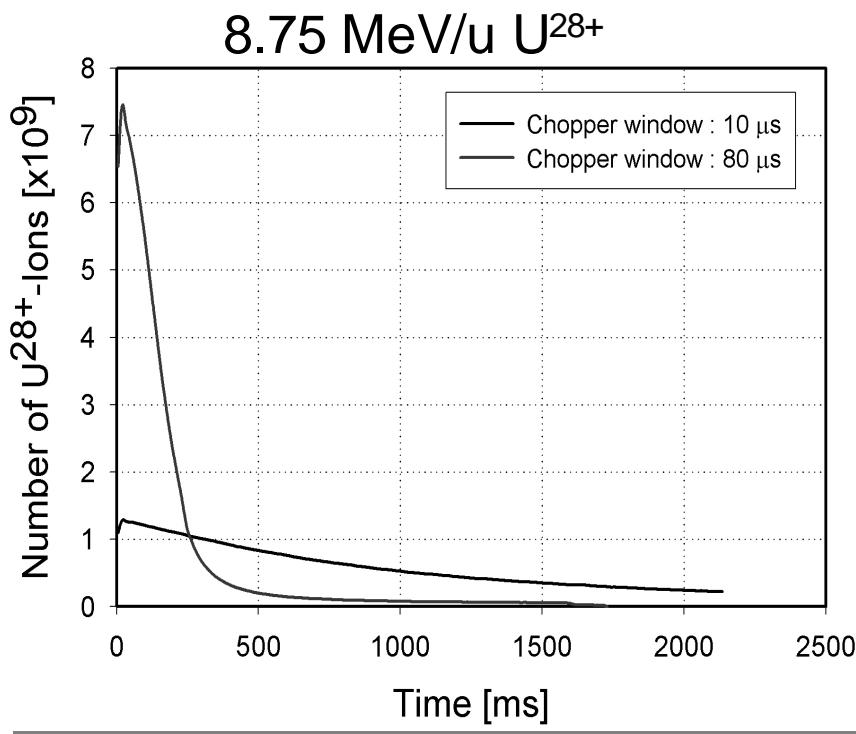


injection

extraction

# Dynamic Vacuum and Beam Lifetime

P. Spiller, December 2001



Desorption processes degenerate the residual gas pressure ( U<sup>28+</sup> case )

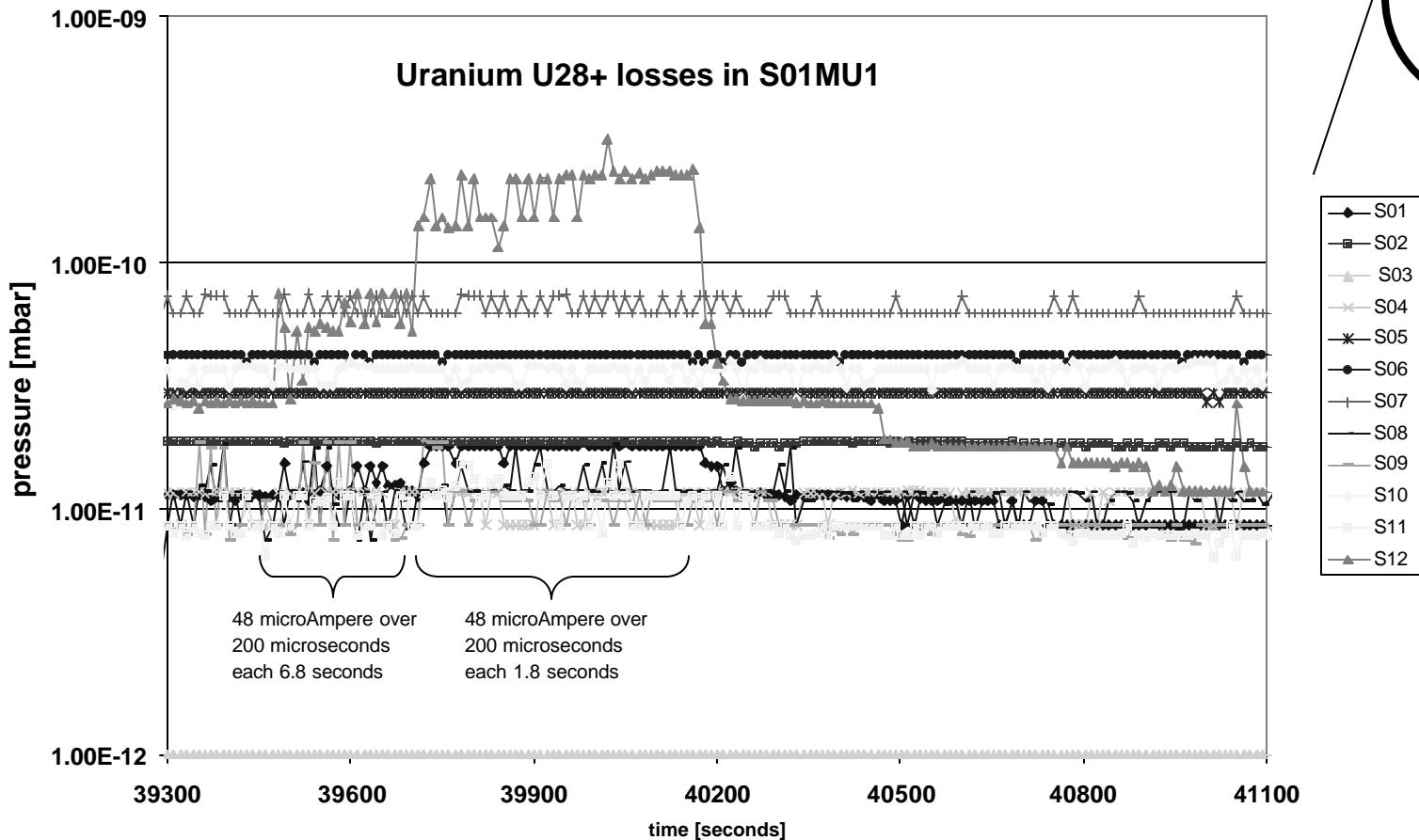
Initiated by :

- Systematic beam losses on acceptance limiting devices (septa) ( 8MeV/u < E <100MeV/u )
- Stripped beam ions ( 8MeV/u < E <100MeV/u )
- Ionized and accelerated residual gas ( E < keV ) : minor effect

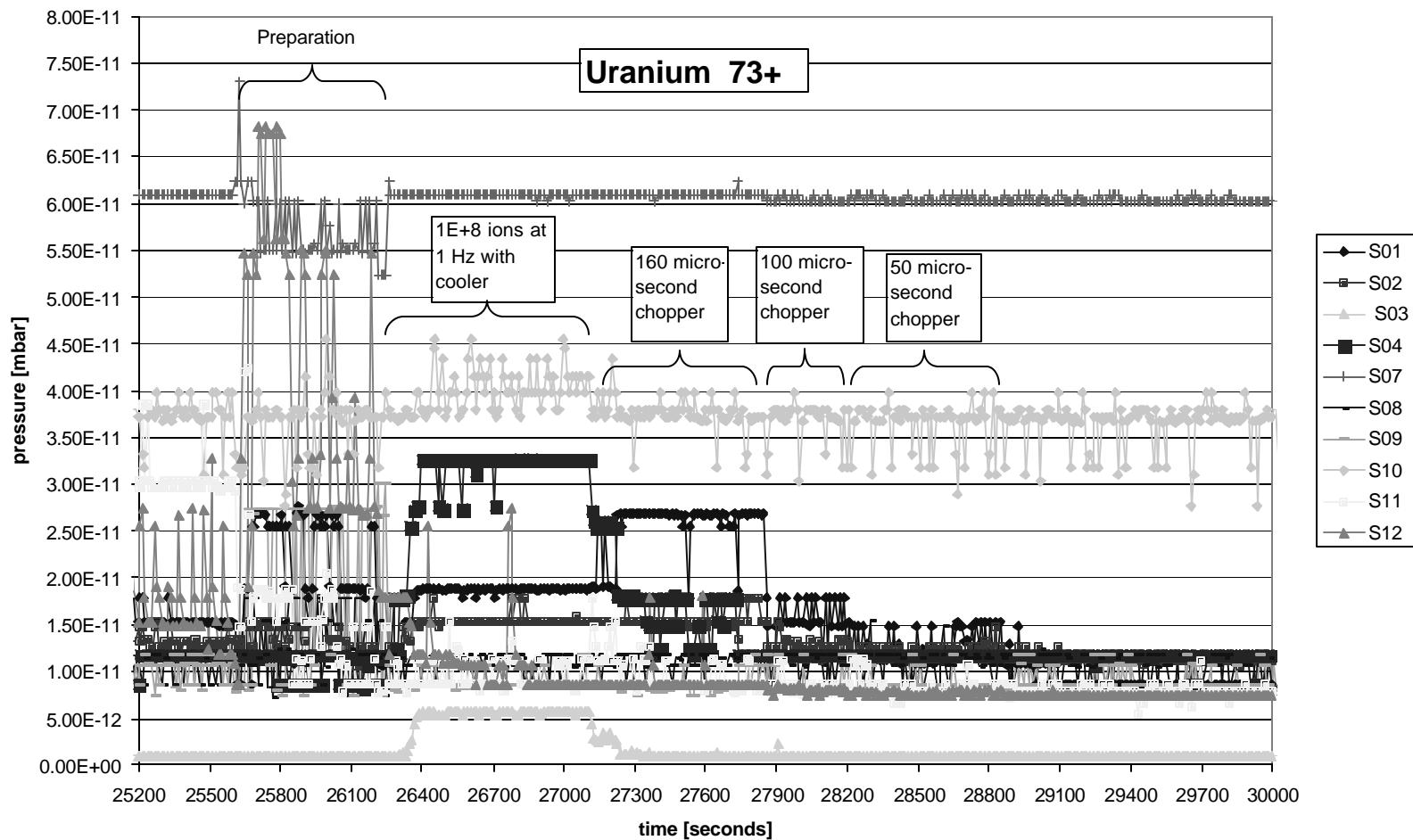
- losses increase with number of injected ions  
( shorter beam life time due to stronger pressure bumps )
- Even at “zero current” ion beam lifetime is too short

# $\text{U}^{28+}$ ion beam operation: total ion beam loss inside first dipole

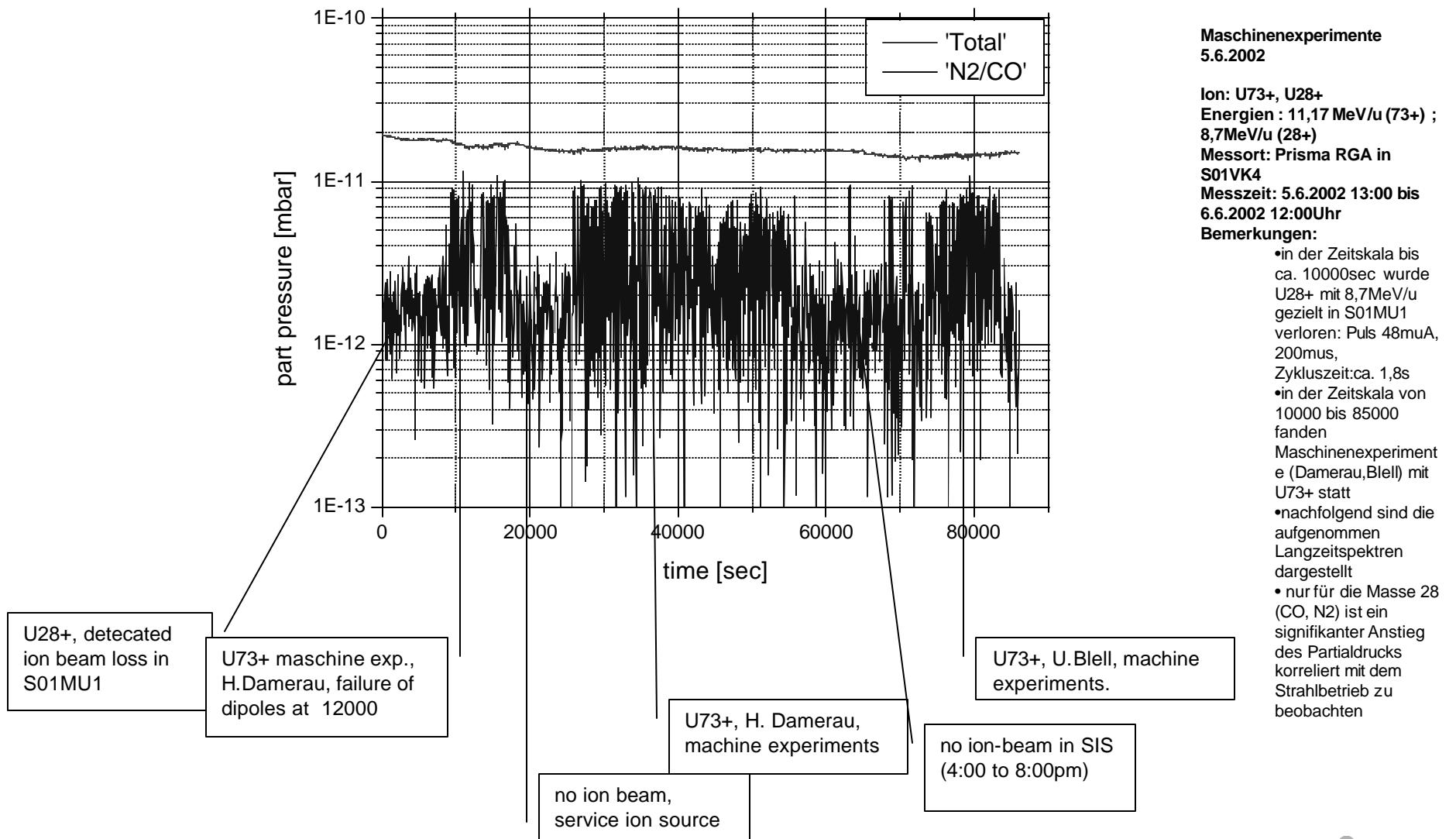
- local pressure rises do not strongly influence neighbouring UHV sections
- Easy measurement at other maschines could help to get high energy data for desorption processes



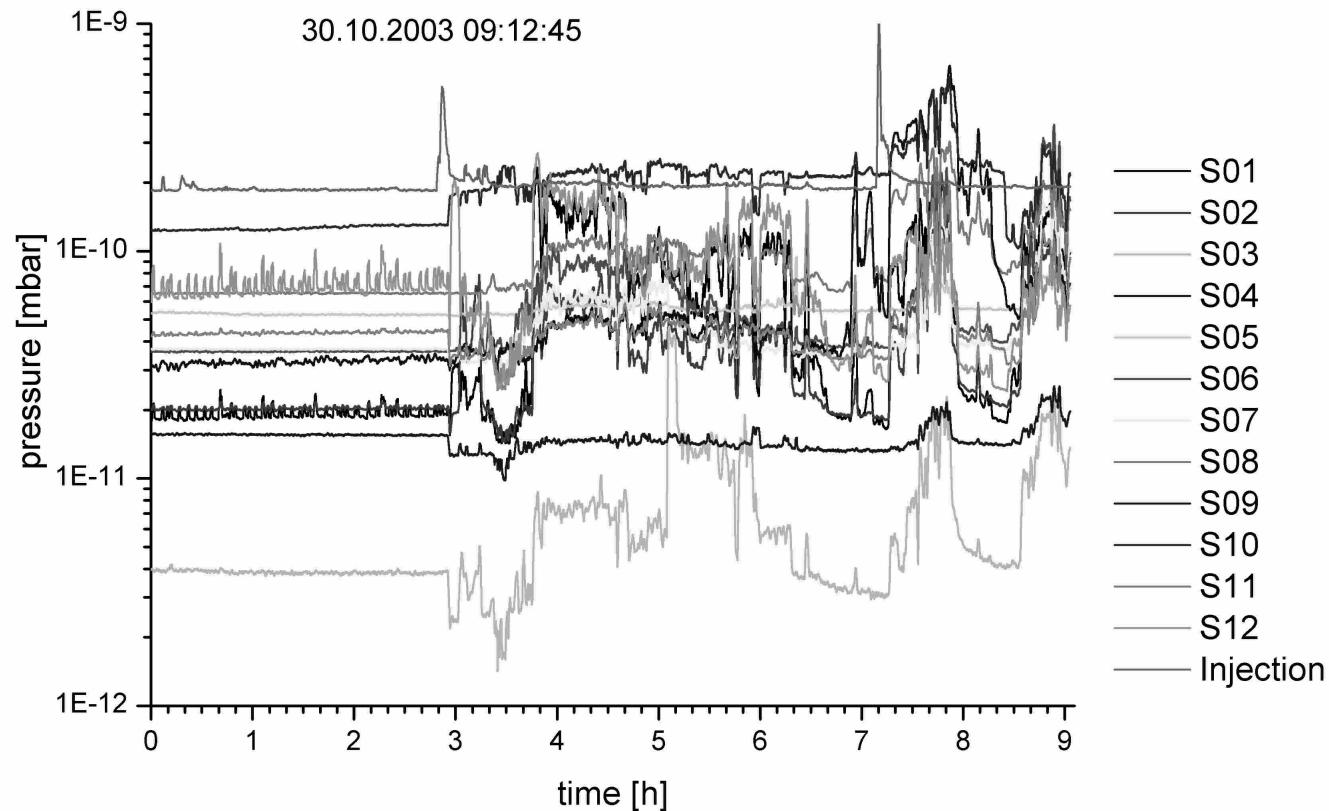
# $U^{73+}$ ion beam operation



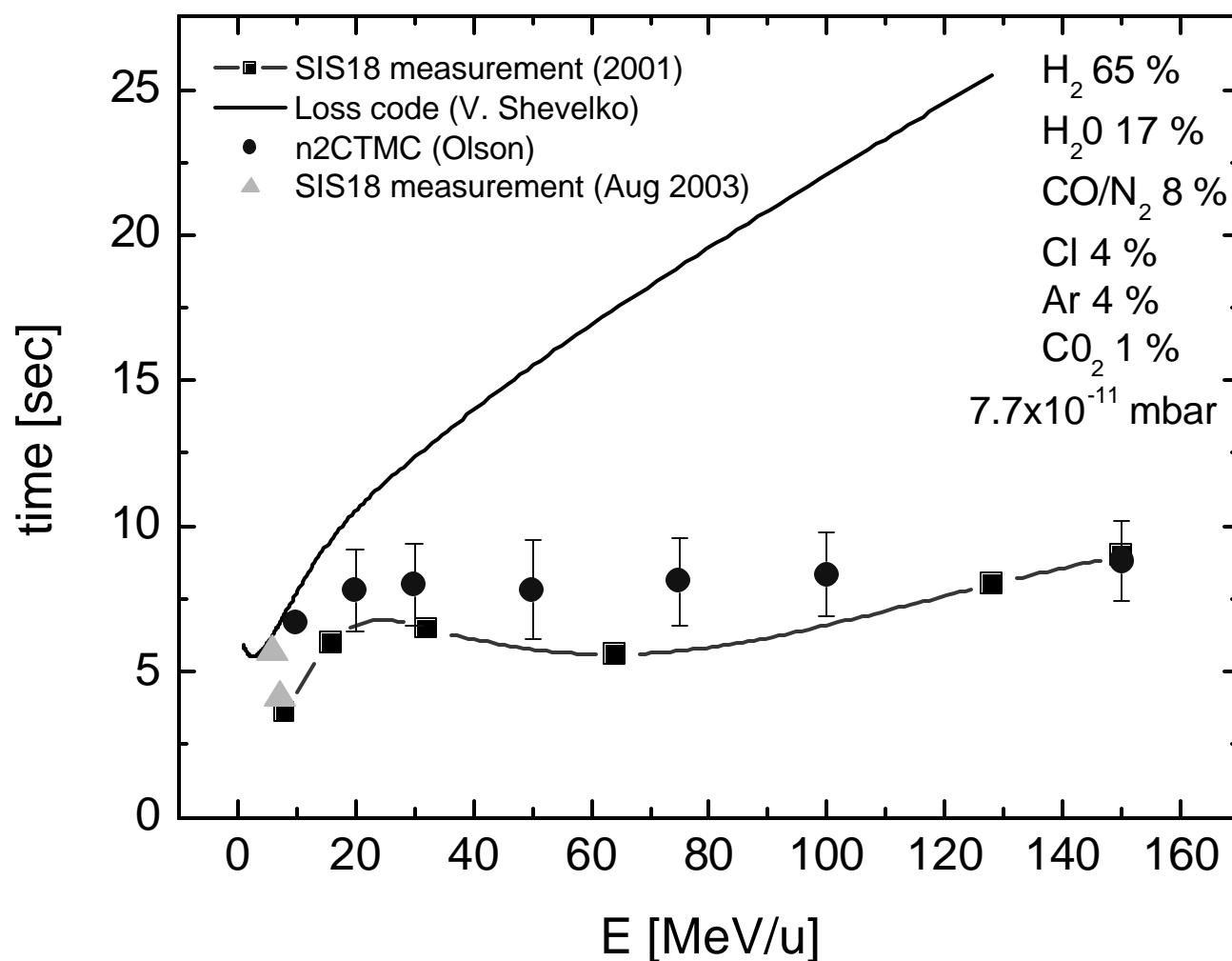
# $\text{U}^{28+}$ / $\text{U}^{73+}$ operation, RGA diagnostic S01 [CO]



# **U<sup>28+</sup> ion beam operation of SIS18 (up to 10<sup>10</sup> injected ions)**



# Lifetime of U<sup>28+</sup> ions in SIS18 at low ion beam intensities (~ 10<sup>8</sup> ions per cycle)



R. Olson et al., GSI Annual Report 2002, 97 (2003)

# Vacuum Requirements for SIS18

**Beam lifetime has to be significantly larger than cycling time of the SIS18  
(Lifetime of at least 10 seconds for all kinds of operation)**

**Total pressure in low  $1 \cdot 10^{-12}$  mbar with a small fraction of high Z  
gases even for highest beam intensities**

## **optimized static conditions:**

- minimized outgassing rate through material and production control, cleaning, bakeout,
- removal of contaminations and "micro-leaks"
- efficient and distributed pumping.

## **optimized dynamic conditions:**

- efficient ion beam loss control,
- low desorption at localized ion beam losses,
- maximized local pumping speed at locations of ion beam loss,
- No beam scrubbing possible due to multi-user operation of SIS18

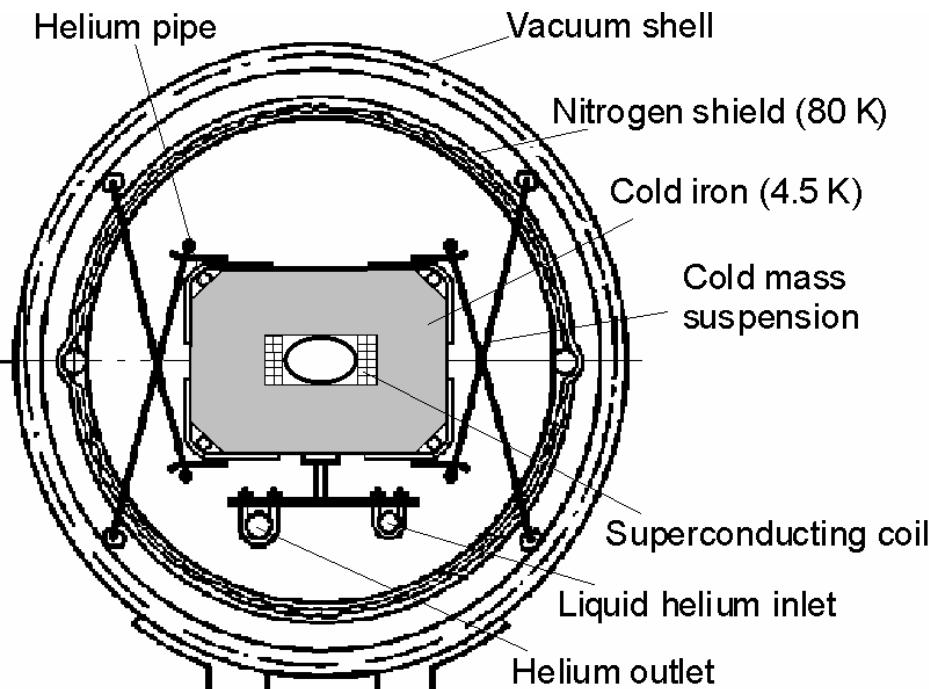
# Optimized Static Conditions:

	2004	2005	2006	2007
Detection and removal of micro-leaks ( $\rightarrow$ Ar !)				
Exchange of contaminated insertions ( $\rightarrow$ CxHy)				
Replacement of all 24 dipole chambers ( $\rightarrow$ bakeout to 300°C, coating?) [existing new spare chambers]				
Replacement of all 12 quadrupole chambers ( $\rightarrow$ bakeout to 300°C, coating?) [prototype and new chambers to be designed and built]				
Ion Pumps: optimized IP regeneration, if necessary: replacement by noble diodes, optimized sublimation cycles ( $\rightarrow$ improved pumping speed)				

# Optimized Dynamic Conditions:

- collimators at locations of known ion beam loss:
  - ✓ injection section / septum      May/June 2003
  - ✓ extraction / septum
- with integrated high pumping speed:
  - cryopump      beginning of 2004
- low desorption materials:
  - experiments at test bench with ion beam      since April 2003
- distributed pumping speed:
  - NEG ?      final decision depends on desorption experiment results

# Cryogenic Systems: Nuclotron Dipole for SIS100



elliptical, 130x65mm

indirectly cooled with pipes and LHe,  
 $T=7-20\text{K}$

$\Delta p = 1\text{bar} \Rightarrow 0.8\text{mm stainless steel wall}$

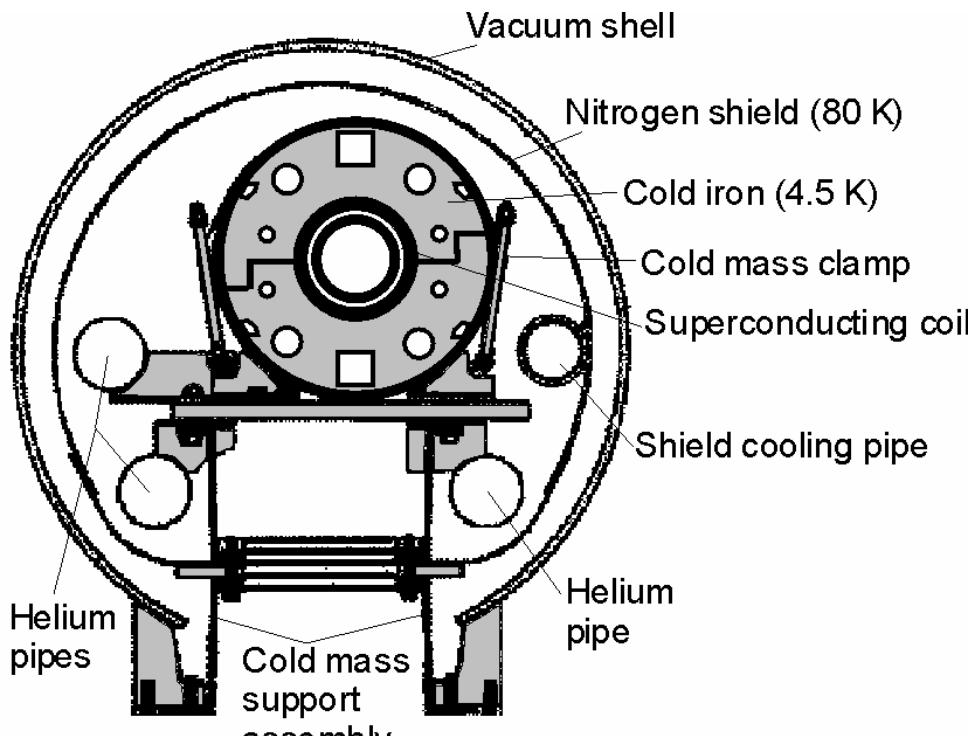
$dB/dt = 4\text{T/s} \Rightarrow 0.5\text{mm stainless steel wall (eddy current)}$

Alternative:

conventional warm magnets with warm beam pipe

In the straight sections of SIS100 (6x60m) the vacuum chambers are at room temperature.

# Cryogenic systems: RHIC Dipole for SIS300



round, diameter=100mm  
directly cooled in LHe-bath,  $T=4.2\text{K}$   
for quench protection  $\Delta p=30\text{bar}$   
 $dB/dt=1\text{T/s}$

# Requirements for warm ( $T=300K$ ) vacuum beam pipes in SIS100/300

- UHV compatible (outgassing rate:  $10^{-13}$  mbarl/(s cm $^2$ ))
- low desorption rate under ion bombardment
- high electric conductivity (image current guidance, impedance)
- non-magnetic, non-magnetizable
- good weldability or other UHV compatible joining techniques, good machinability
- moderate costs
- good thermal conductivity
- high mechanical stability at high temperature [bake out @573K for stainless steel]
- low thermal expansion

## Some (in principle) possible materials:

Stainless steel, aluminum and aluminum alloys (?), copper and copper alloys (Al-Cu), titanium and titanium alloys, beryllium(???)

# Comparison cold and warm vacuum chambers

	Cold Vacuum Chambers	Warm Vacuum Chambers
<b>Ion Induced Desorption h</b>	$H_2^+ \rightarrow H_2$ $h \sim 10^3-10^5$ @ 0.5-10keV  no high energy ion induced desorption data available!! But no pressure increase observed in cold sections of RHIC! (?)	$H_2^+ \rightarrow H_2$ $h \sim 1$ @ 0.5keV (impact of secondary residual gas ions)  $h \sim 10^3-10^6$ @ 1 MeV/u-10 GeV/u (primary high energy ions)
<b>Pumping speed corresponds to sticking coefficient</b>	<b>Sticking Coefficient @ T= 5-20K</b>  $H_2$ : < 0.5 $CO$ : ~ 1 $CO_2$ : ~ 1 $CH_4$ : ~ 1	<b>NEG</b>  $H_2$ : 0.007 $CO/CO_2$ : 0.5  no pumping speed for chemical inert gases (Ar, $CH_4$ , ...)

# Open Questions

## Warm Vacuum Sections:

- **Ion induced desorption yield at high energies? (experimental program under way at the test bench and at SIS18 directly) Next step: Measurements at UNILAC, ERDA analysis of targets**
- **Electron cloud effects?**

## Cold Vacuum Sections:

- **Ion induced desorption yields at 4K for different materials? (experimental program under way)**
- **Required wall thickness and material for cold chambers in fast ramped magnets? (image current, eddy current, additional supports, heat load, impedance, field quality...) (first studies at University of Magdeburg). Next steps: construction / manufacturing / testing of vacuum chamber samples → prototyping**

# Possible UHV collaboration inputs

- NEG coating of vacuum chambers (SIS-dipole, 4-pole,... ?)
- experiments on low desorption yield materials
- design work on cryogenic vacuum chambers (SIS100,SIS300)
- Material/surface physics input to understand the desorption physics
- .....

## GSI UHV group:

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Savino, K. Welzel**